Response of the Antarctic ice sheet to a warming ocean using the POPSICLES coupled ice-sheet–ocean model

Dan Martin

Lawrence Berkeley National Laboratory

August 21, 2015

U.S. DEPARTMENT OF ENERGY | Office of Science

BISICLES

BERKELEY LAB

P I K

Los Alamos NATIONAL LABORATORY EST. 1943

University of BRISTOL

Toward

Response of the Antarctic ice sheet to a warming ocean using the POPSICLES coupled ice-sheet–ocean model

Dan Martin

Lawrence Berkeley National Laboratory

August 21, 2015

U.S. DEPARTMENT OF ENERGY | Office of Science | BISICLES | BERKELEY LAB | PIK | Los Alamos NATIONAL LABORATORY EST. 1943 | University of BRISTOL

Joint work with:

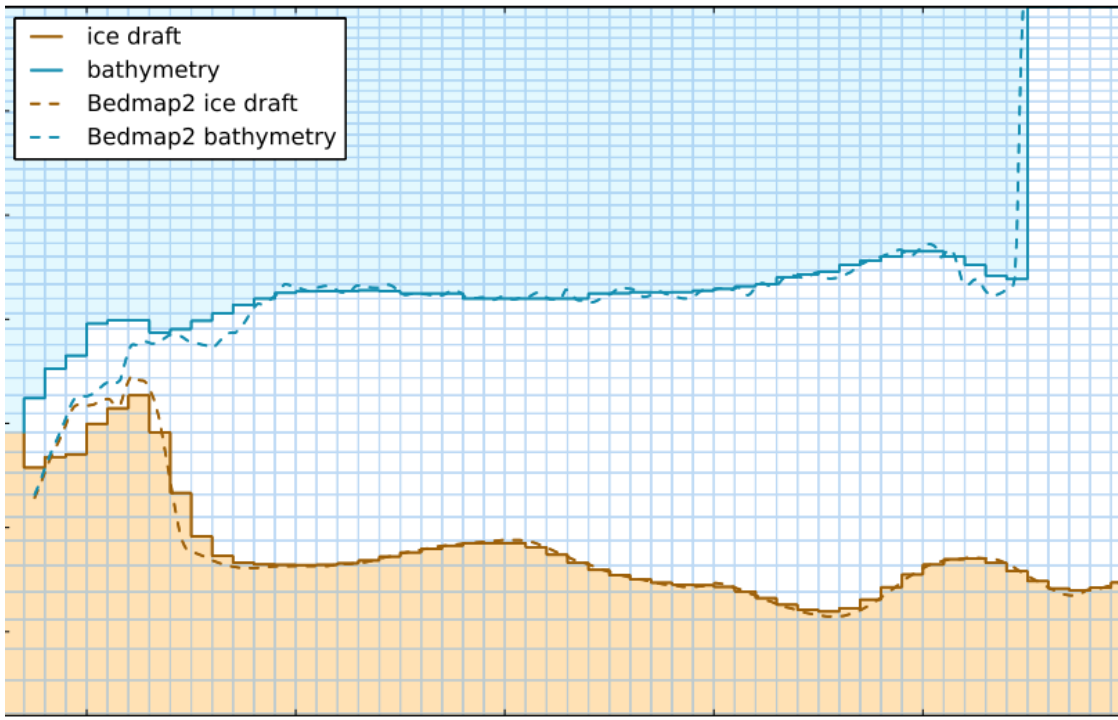
- **Xylar Asay-Davis** (Potsdam-PIK)
- Stephen Cornford (Bristol)
- Stephen Price (LANL)
- Doug Ranken (LANL)
- Mark Adams (LBNL)
- Esmond Ng (LBNL)
- William Collins (LBNL)

Coupled Ice and Ocean Models:

- Ocean Circulation Model: POP2x
- Ice Sheet: BISICLES (CISM-BISICLES)
- POP + BISICLES = POPSICLES

POP and Ice Shelves

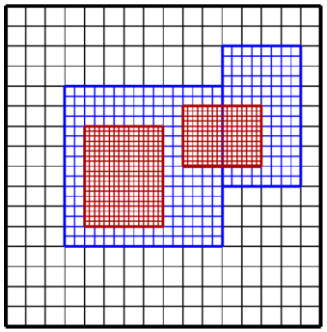
- Parallel Ocean Program (POP) Version 2
  - Ocean model of the Community Earth System Model (CESM)
  - z-level, hydrostatic, Boussinesq
- Modified for Ice shelves:
  - partial top cells
  - boundary-layer method of Losch (2008)

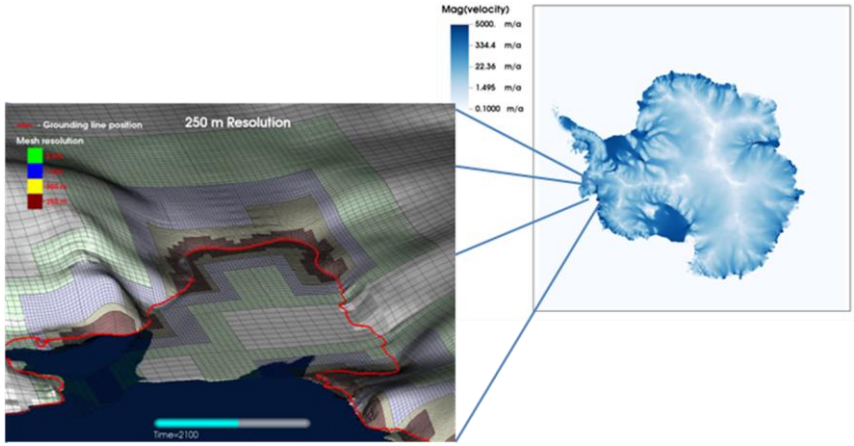


- Melt rates computed by POP (Jenkins 3-equation formulation):
  - sensitive to vertical resolution
  - nearly insensitive to transfer coefficients, tidal velocity, drag coefficient

BISICLES Ice Sheet Model

- Scalable adaptive mesh refinement (AMR) ice sheet model
  - Dynamic local refinement of mesh to improve accuracy
- Chombo AMR framework for block-structured AMR
  - Support for AMR discretizations
  - Scalable solvers
  - Developed at LBNL
  - DOE ASCR supported (FASTMath)
- Collaboration with Bristol (U.K.) and LANL
- Variant of "L1L2" model (Schoof and Hindmarsh, 2009)
- Coupled to Community Ice Sheet Model (CISM).
- Users in Berkeley, Bristol, Beijing, Brussels, and Berlin…





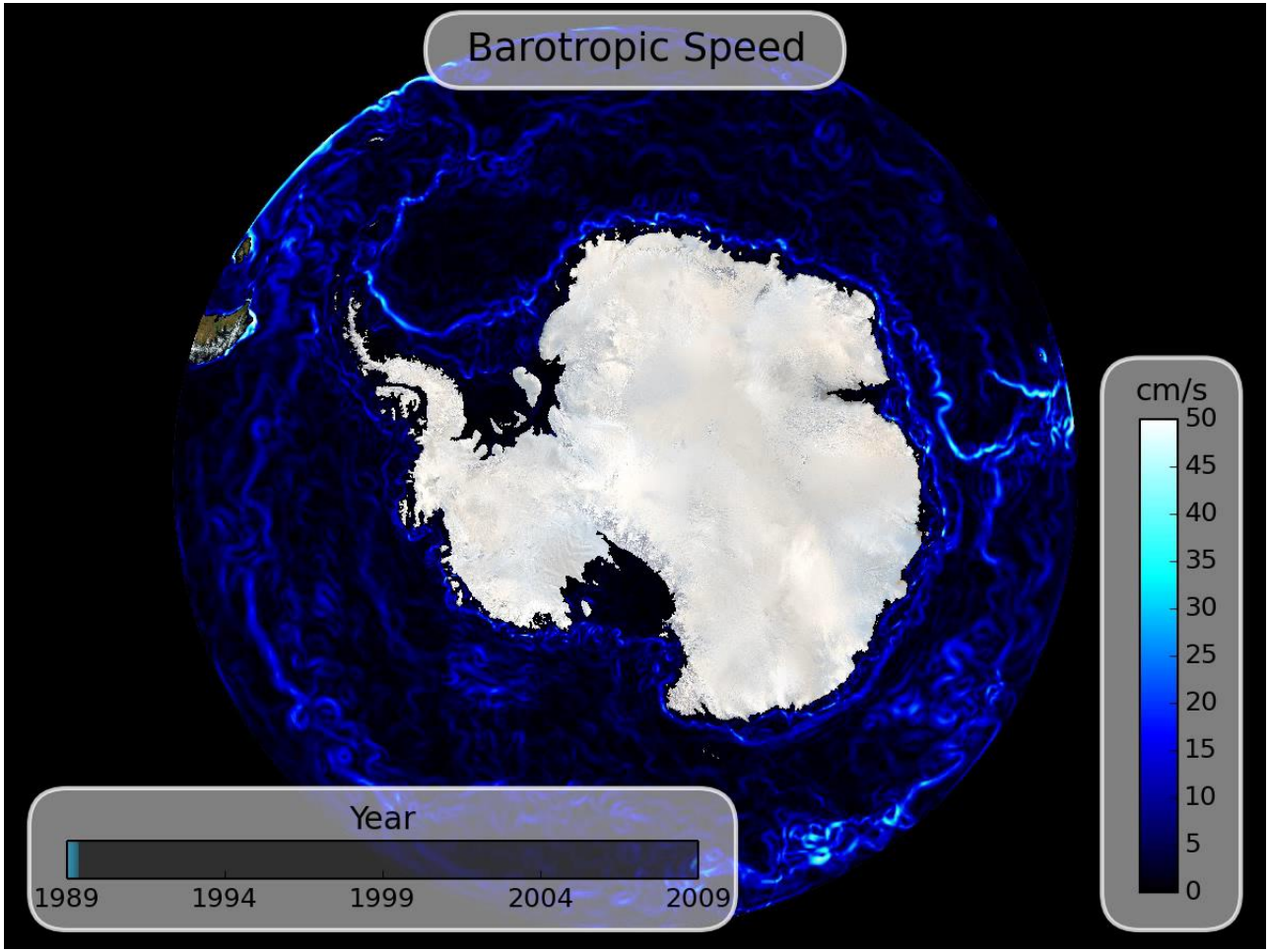
Coupling: Synchronous-offline

- Monthly coupling time step ~ based on experimentation
- BISICLES → POP2x: (instantaneous values)
  - ice draft, basal temperatures, grounding line location
- POP2x → BISICLES: (time-averaged values)
  - (lagged) sub-shelf melt rates
- Coupling offline using standard CISM and POP netCDF I / O
- POP bathymetry and ice draft recomputed:
  - smoothing bathymetry and ice draft, thickening ocean column, ensuring connectivity
  - T and S in new cells extrapolated iteratively from neighbors
  - barotropic velocity held fixed; baroclinic velocity modified where ocean column thickens/thins

Antarctic-Southern Ocean Coupled Simulations

POP setup:

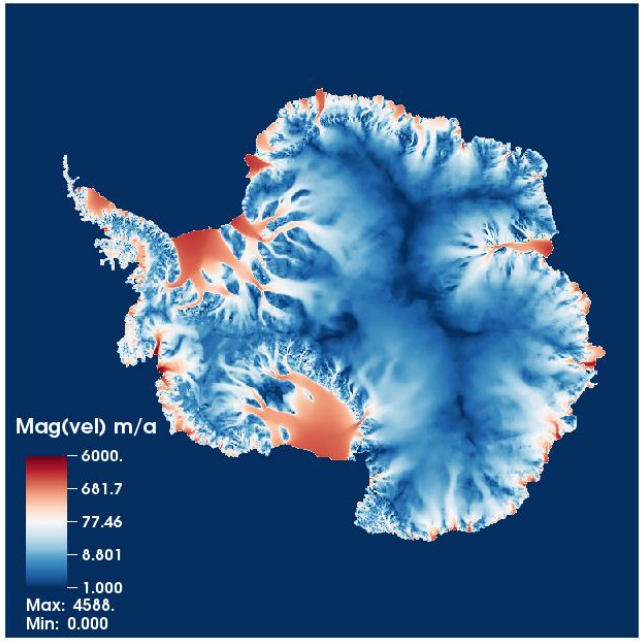
- Regional southern ocean domain (50-85°S)
- ~5 km (0.1°) horizontal res.
- 80 vertical levels (10m - 250m)
- Initialize with stand-alone (20 years) run;
- Bedmap2 geometry
- Force with CORE InterAnnual forcing
- Monthly restoring to WOA at northern boundary

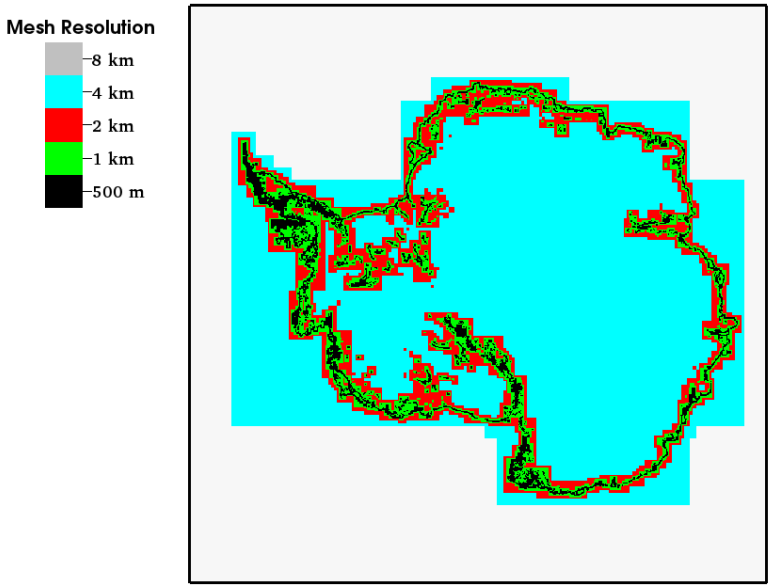


Antarctic-Southern Ocean Coupled Simulations

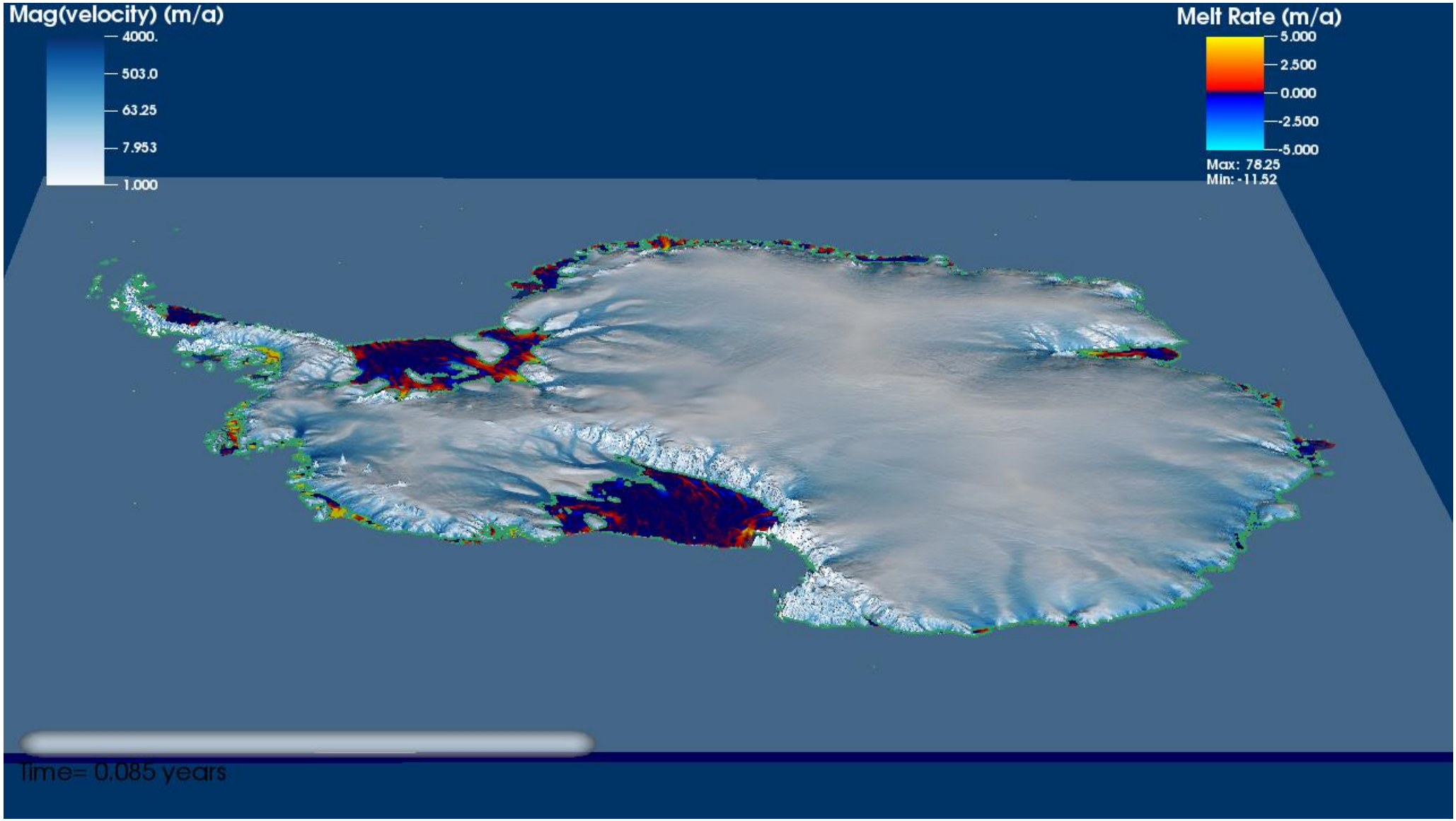
BISICLES setup:

- Full-continent Bedmap2 (Fretwell, 2013) geometry
- Temperature field from Pattyn (2010)
- Initialize to match Rignot (2011) velocities
- 500m finest resolution (adaptive mesh refinement)
- **Initialize SMB to "steady state" using POP standalone melt rate**

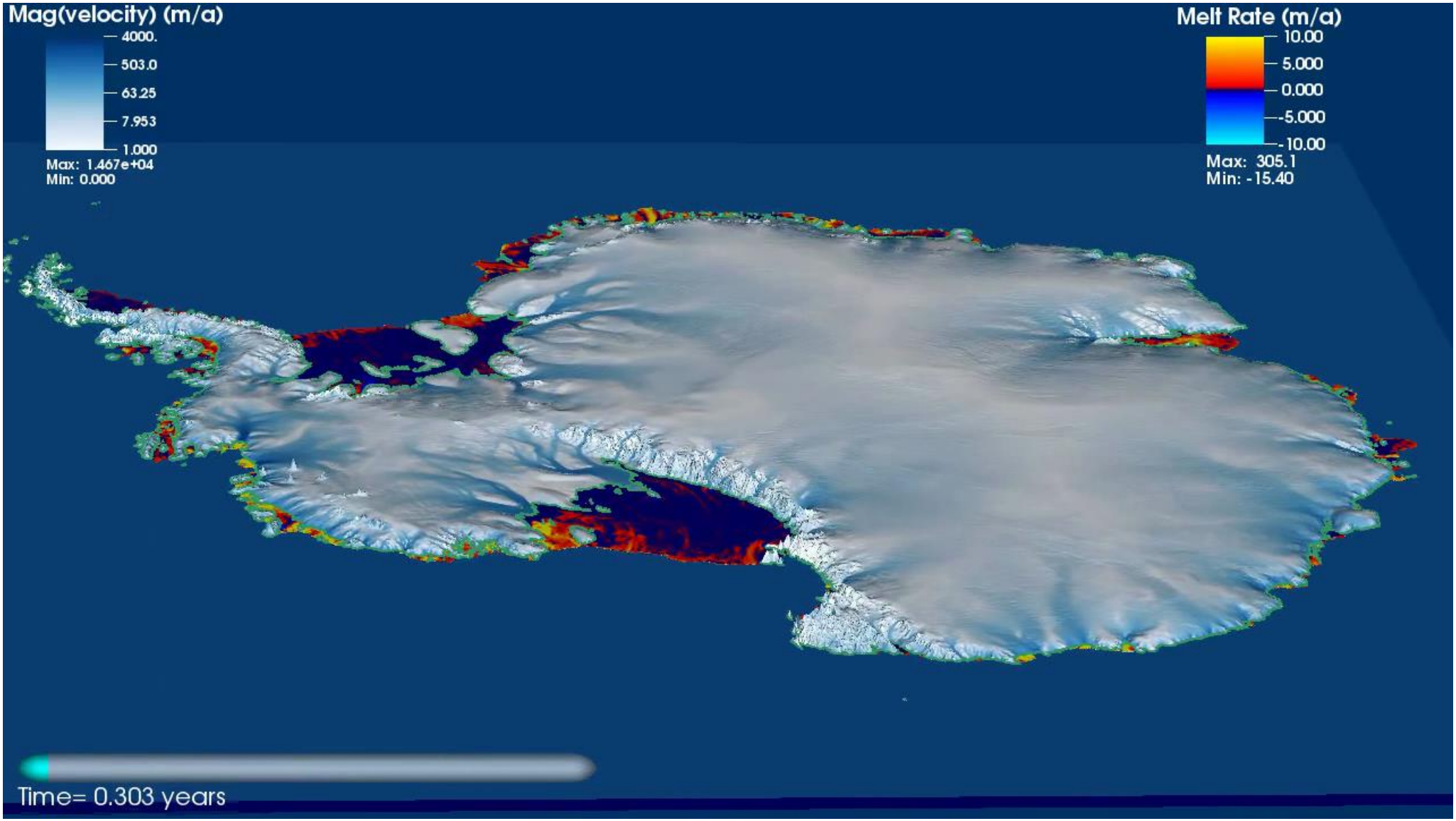




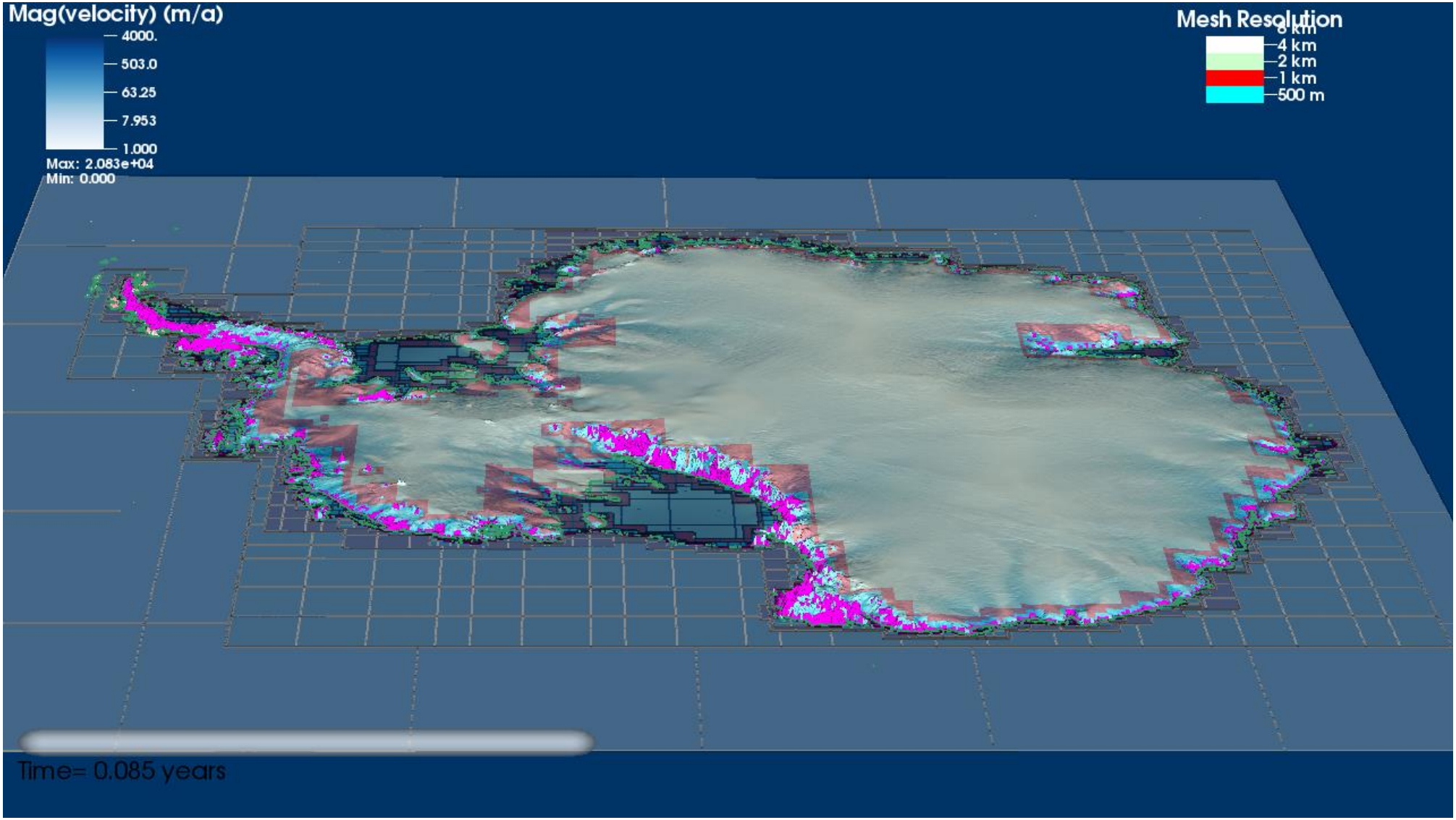
Antarctic-Southern Ocean Coupled Sims (cont)



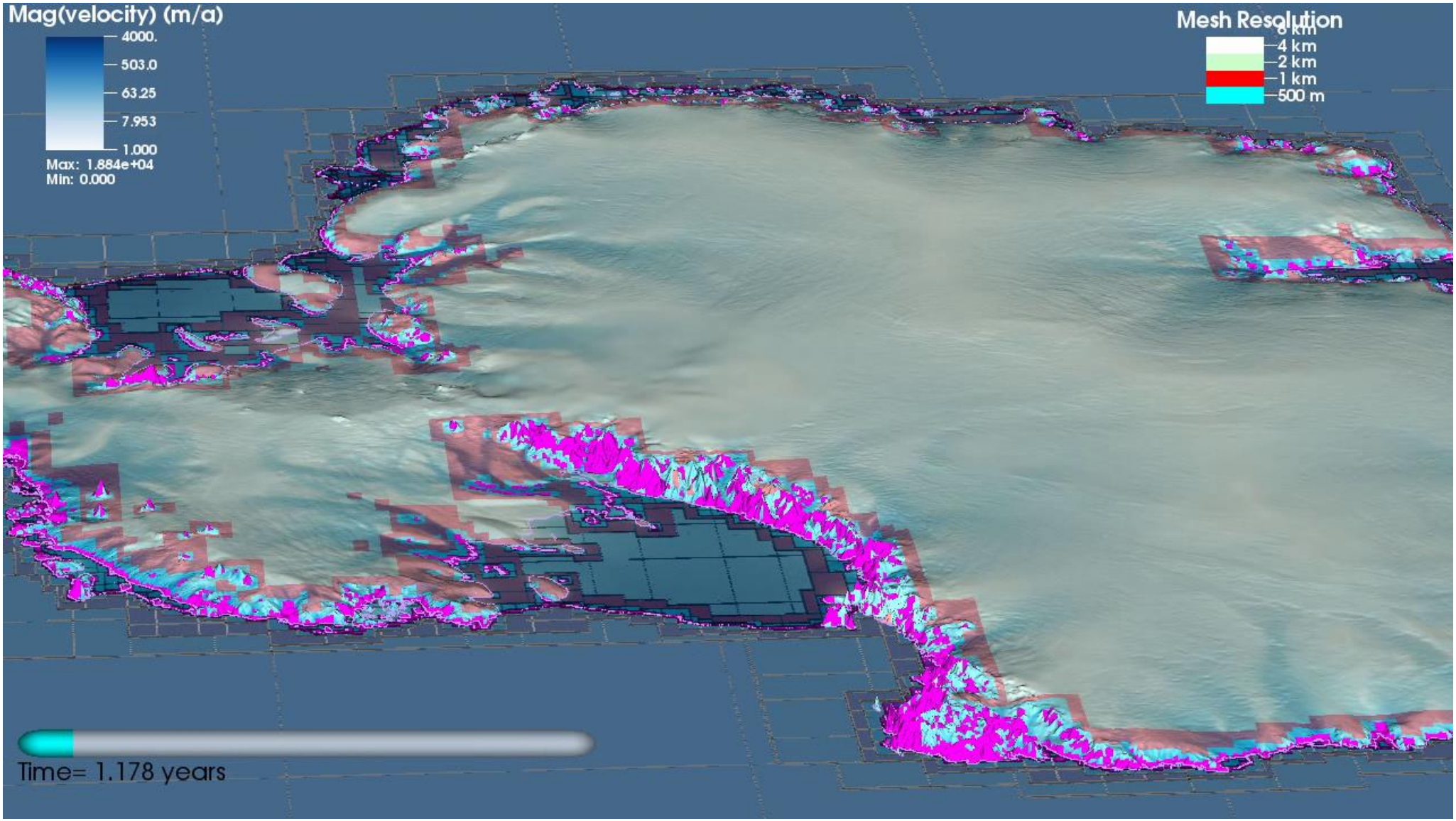
Antarctic-Southern Ocean Coupled Sims (cont)



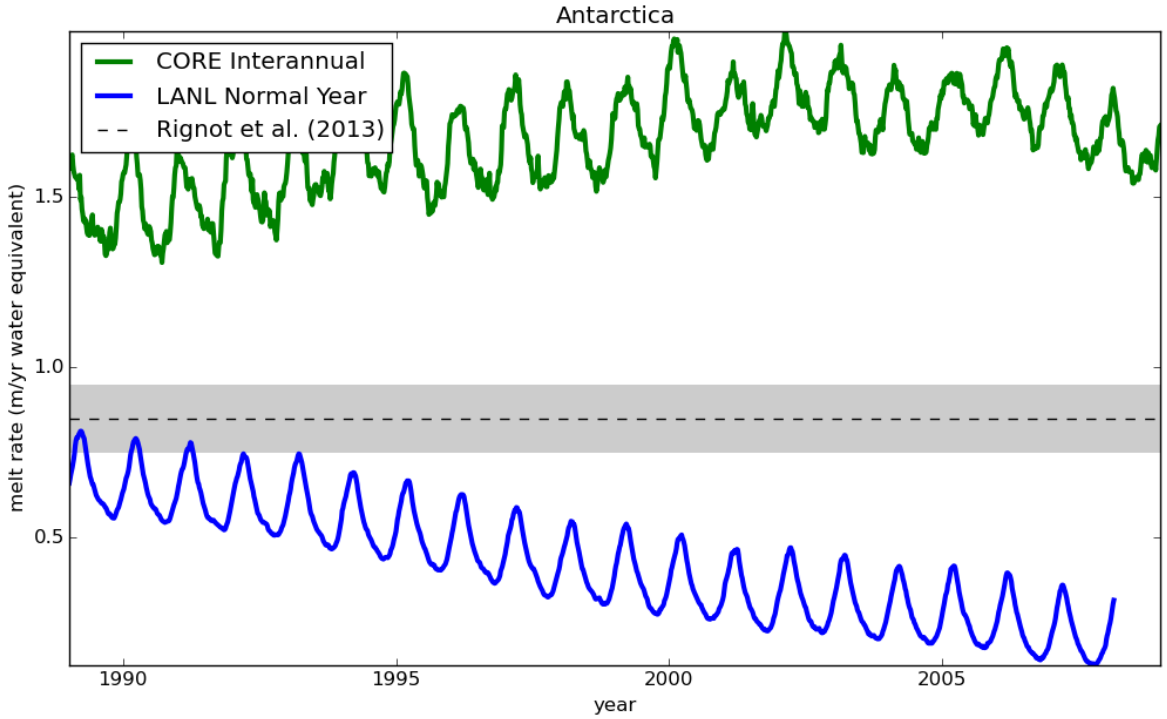
Antarctic-Southern Ocean Coupled Sims (cont)



Antarctic-Southern Ocean Coupled Sims (cont)



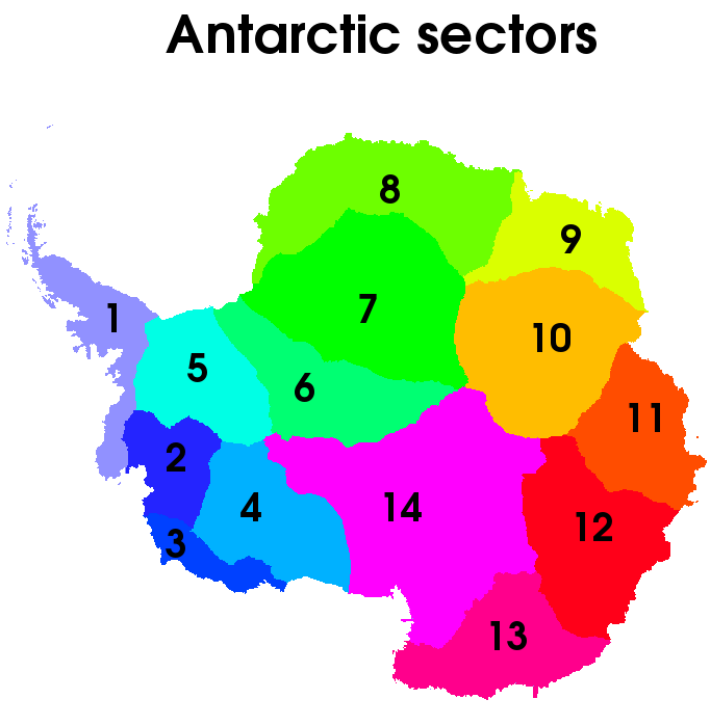
CORE-IAF: Impact on melt rates

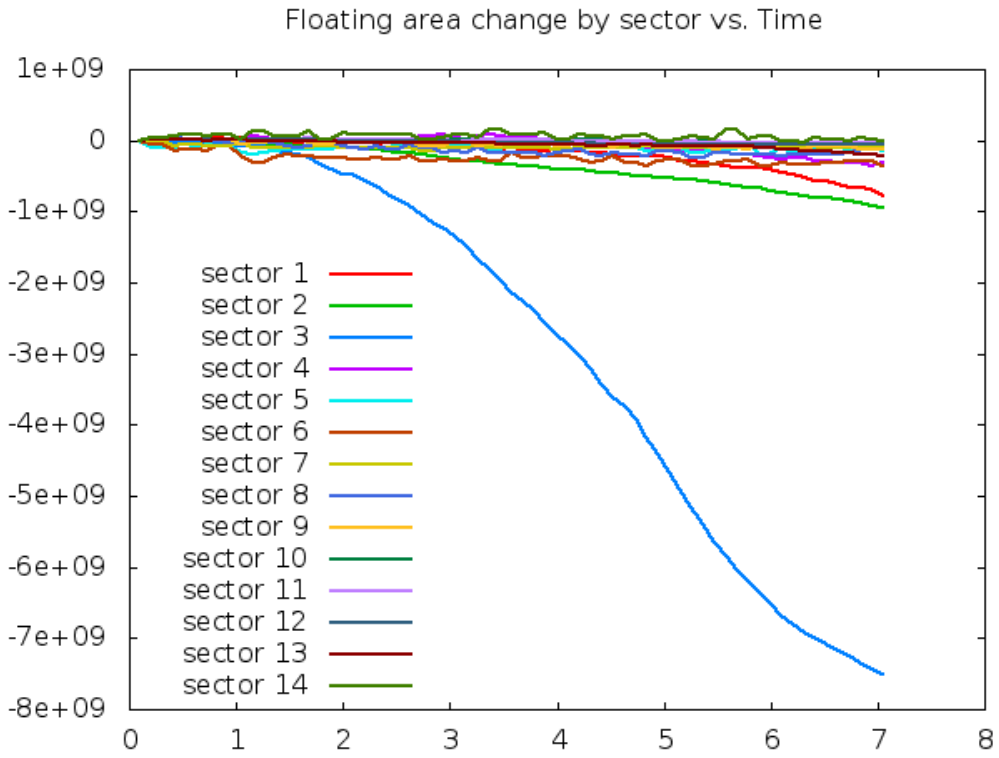


CORE-IAF forcing introduces warm bias…

- **Mixing of CDW into upper ocean**
- Too much stratification from freshwater forcing
- Lack of Dynamic Sea Ice?

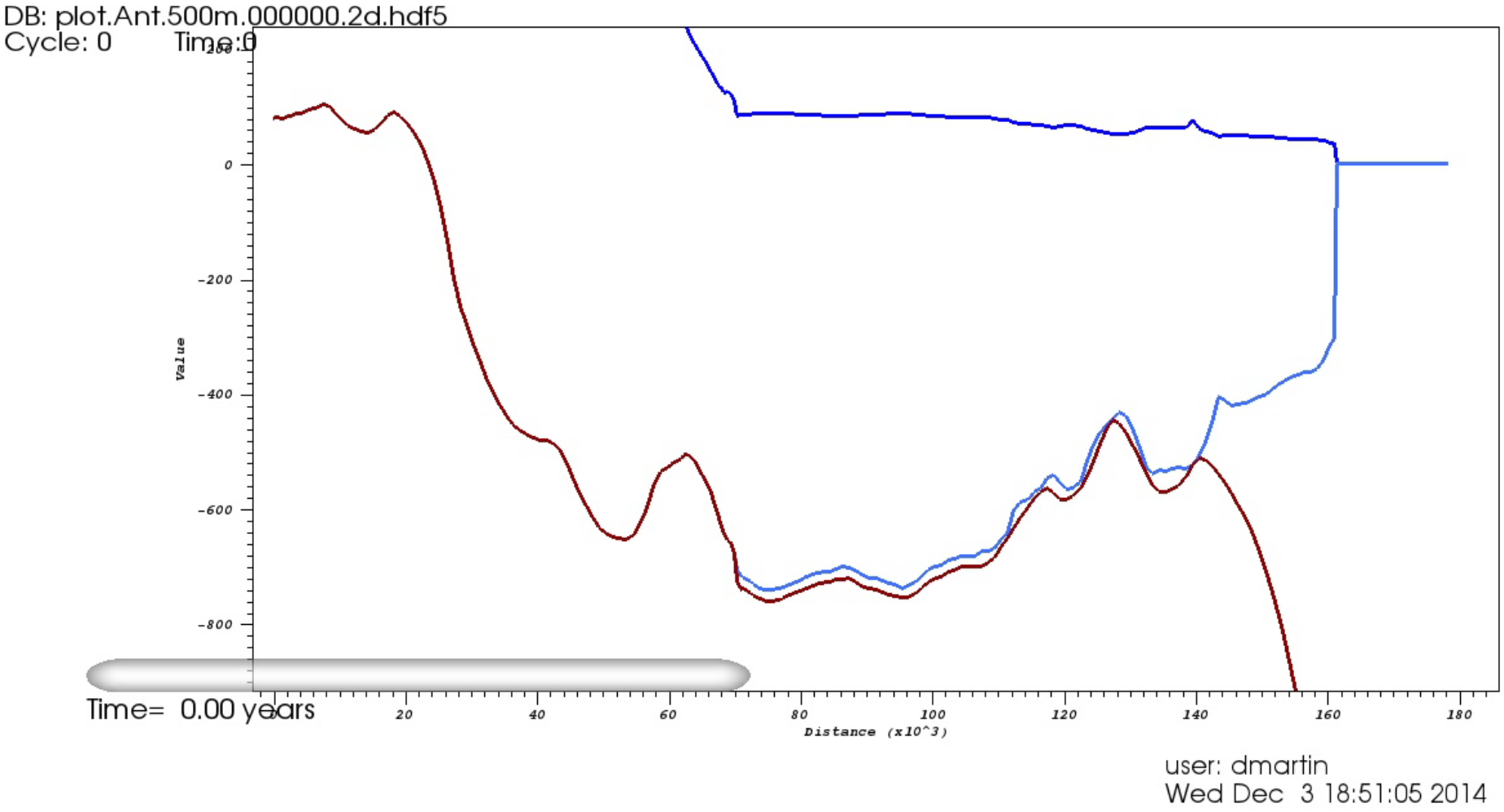
Coupled Antarctica: Ice sheet response





- Response dominated by loss of floating area in a few sectors (**Getz**!)
- This was a **warming** scenario?
- **What happened?** (Getz sector!)

Getz Ice shelf -- Regrounding instability



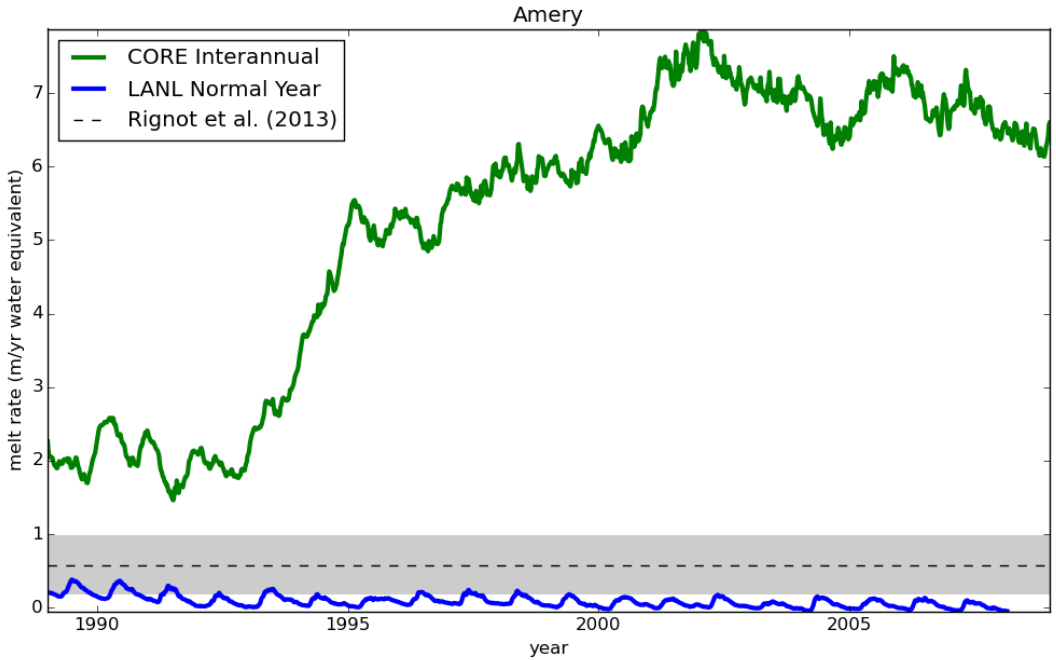
Getz Ice shelf -- Regrounding instability (cont)

What happened?

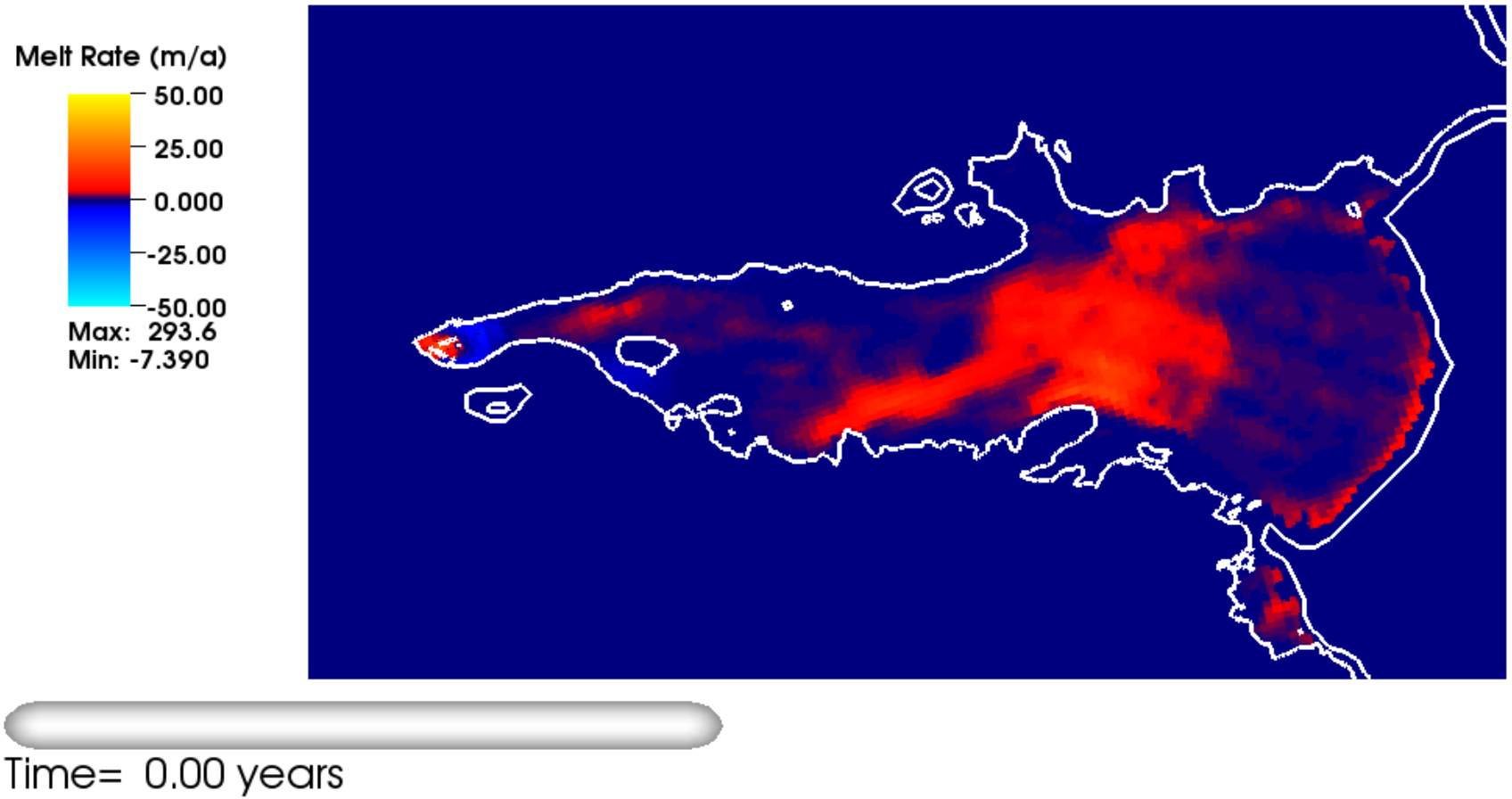
- Bedmap2 – poorly constrained subshelf bathymetry
  - "Made stuff up" -- reasonable from the ice-sheet perspective
  - Resulted in very thin (< 100m) subshelf cavities under the ice
- Nominal/standalone POP2x melt rates fairly high
- Large synthetic accumulation field to balance melt and keep shelf in steady state
- Time-dependent runs – ***instability***
  - Small relative fluctuations in melt-rate forcing can result in thickness changes which are **O(** cavity thickness)
  - Localized grounding
  - Subself melting turns off – unbalanced (and large!) accumulation
  - Leads to more regrounding -> more unbalanced melt….

Warmwater incursion – Amery

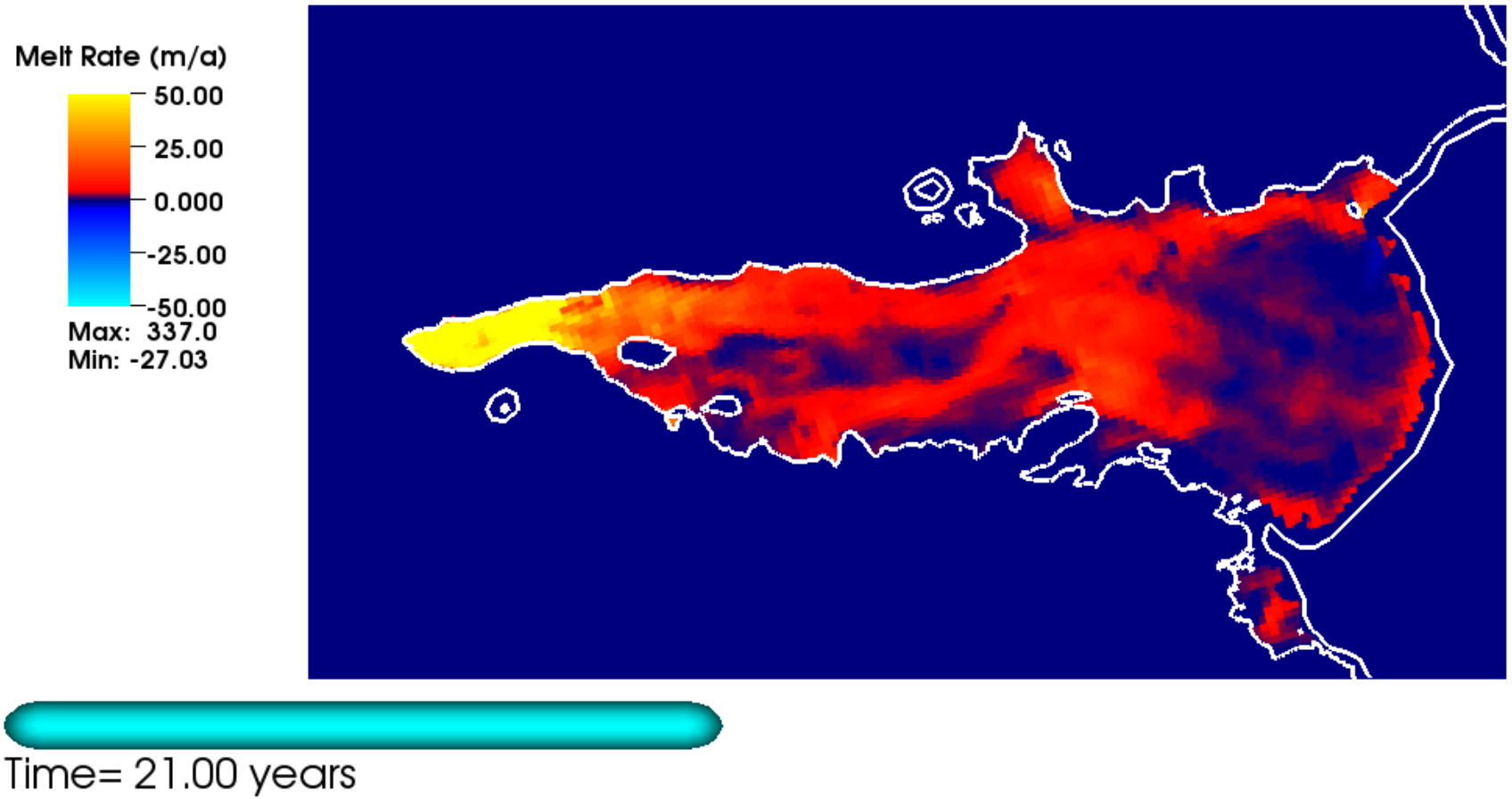
- Warmwater incursion in Amery basin
- Increased melt rate – front reaches end of cavity in 9-10 years
- Moderate GL retreat



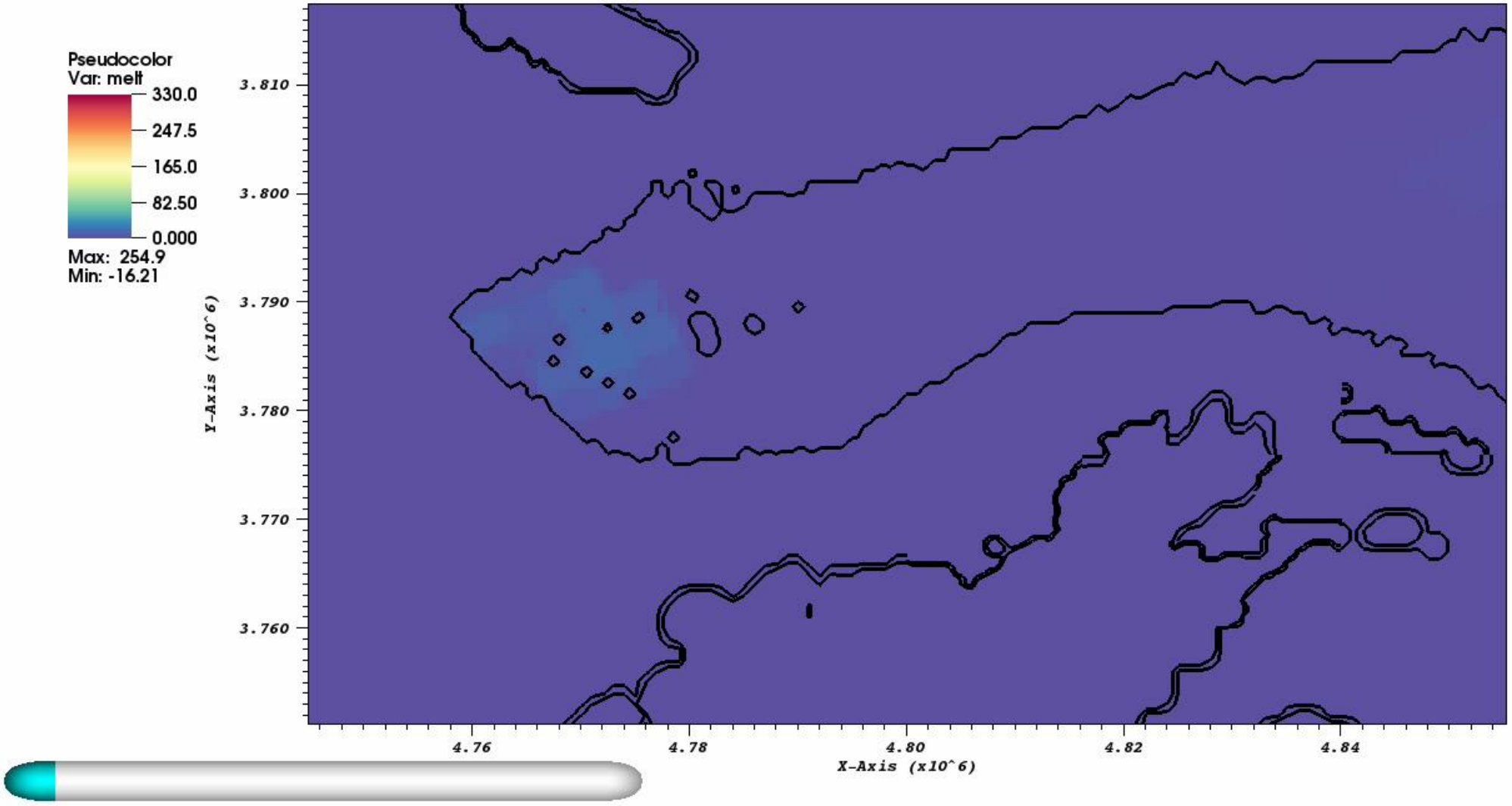
Warmwater Incursion – Amery (cont)



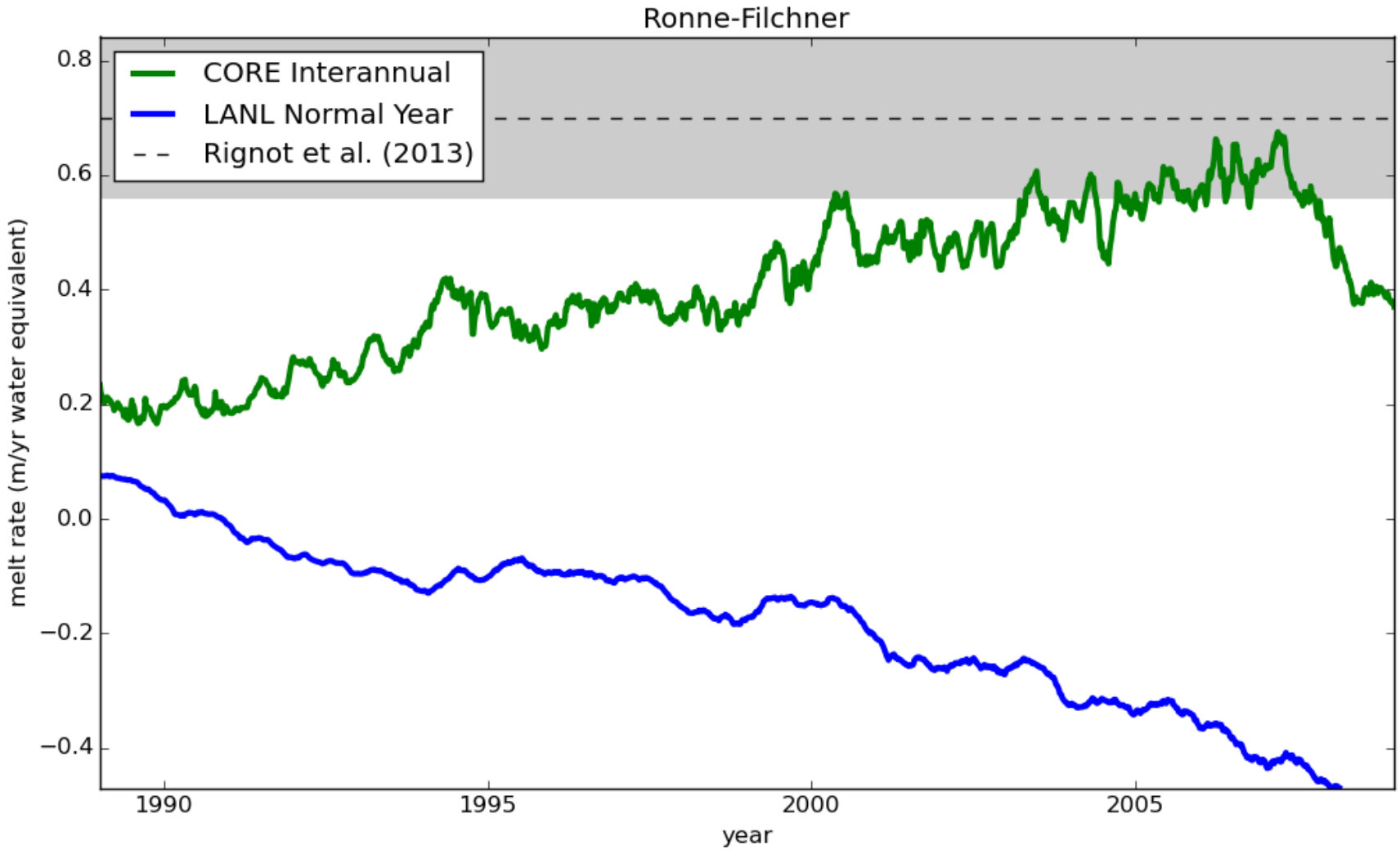
Warmwater Incursion – Amery (cont)



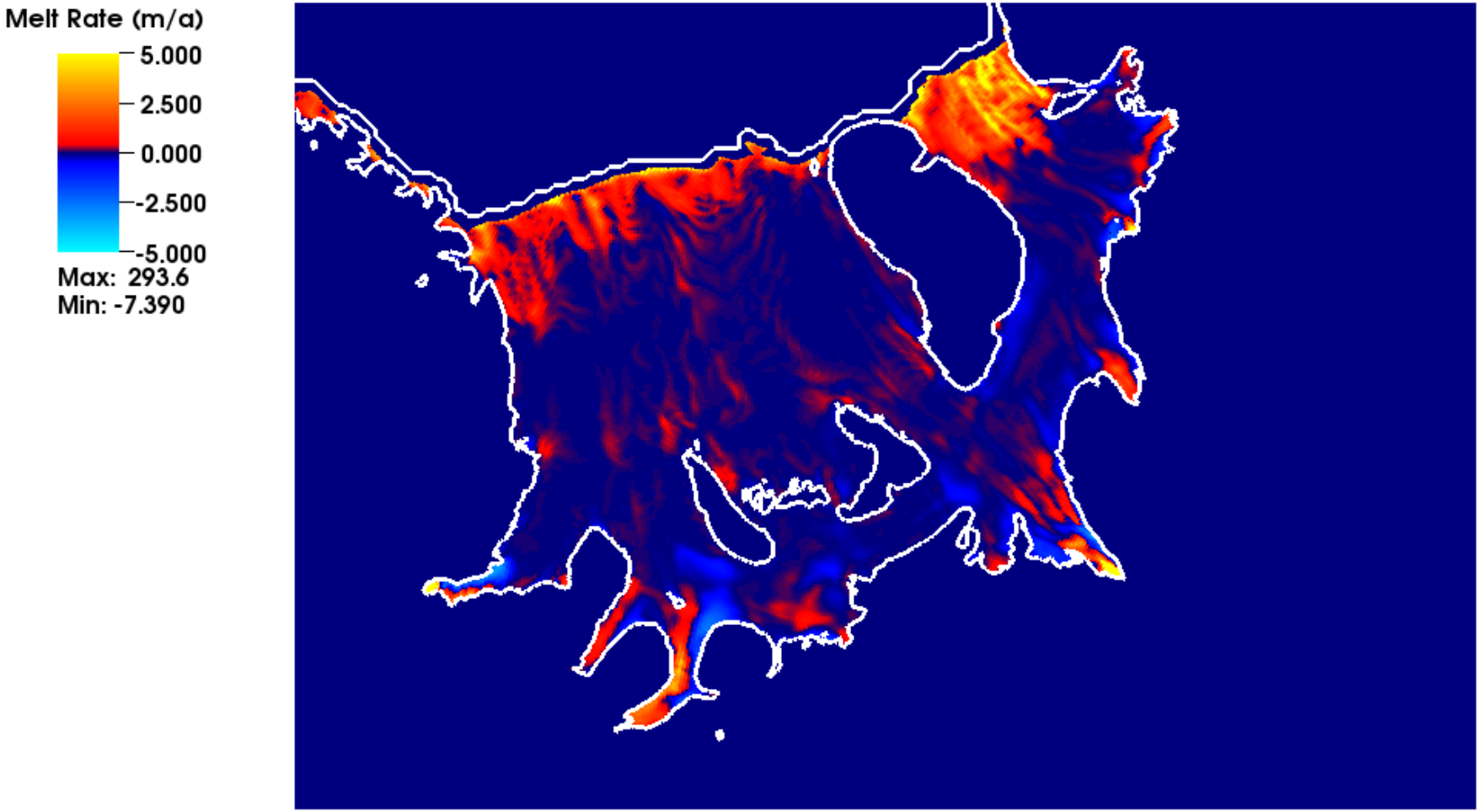
Warmwater incursion – Amery (cont)



Ronne-Filchner

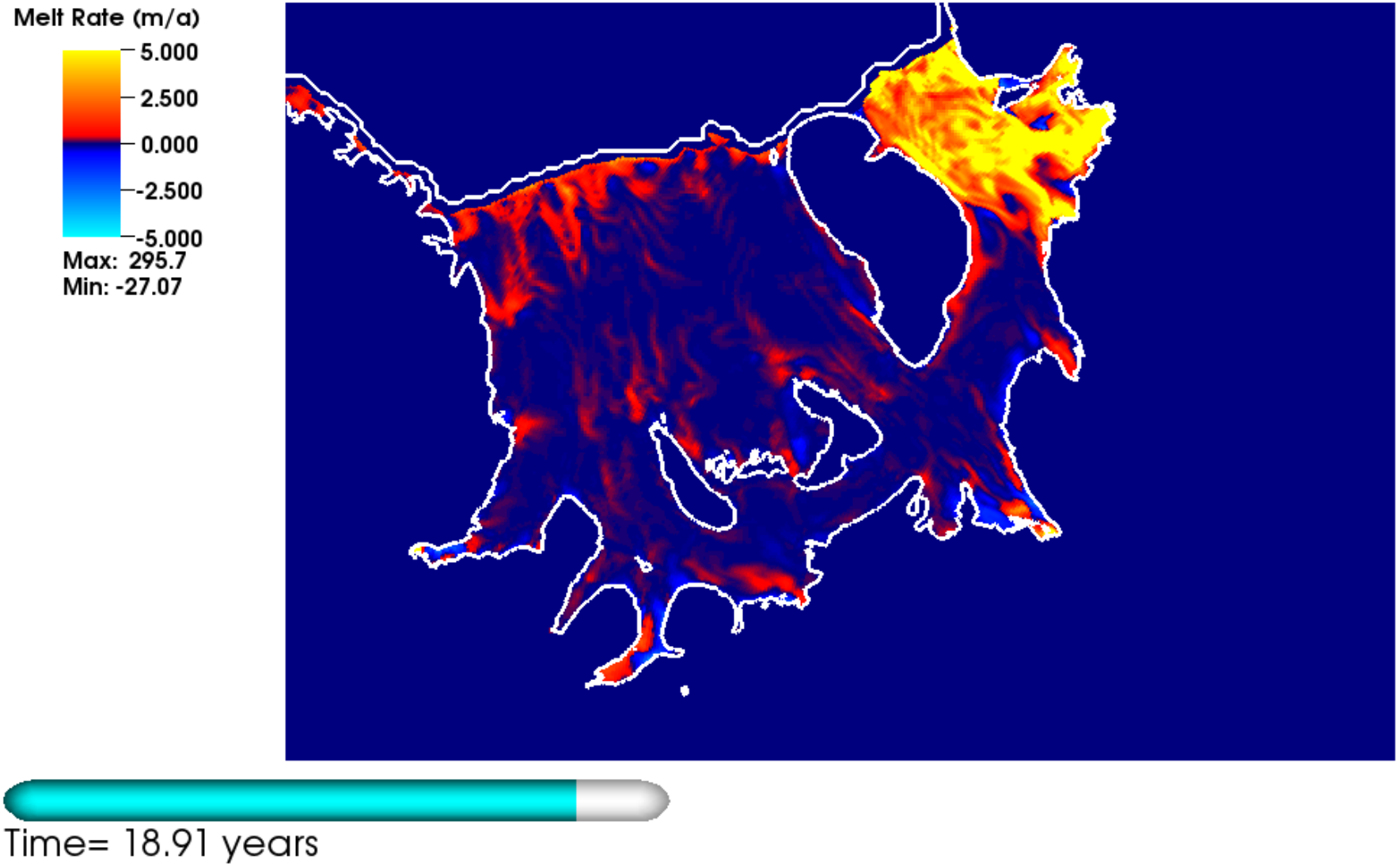


Ronne-Filchner Ice Shelf

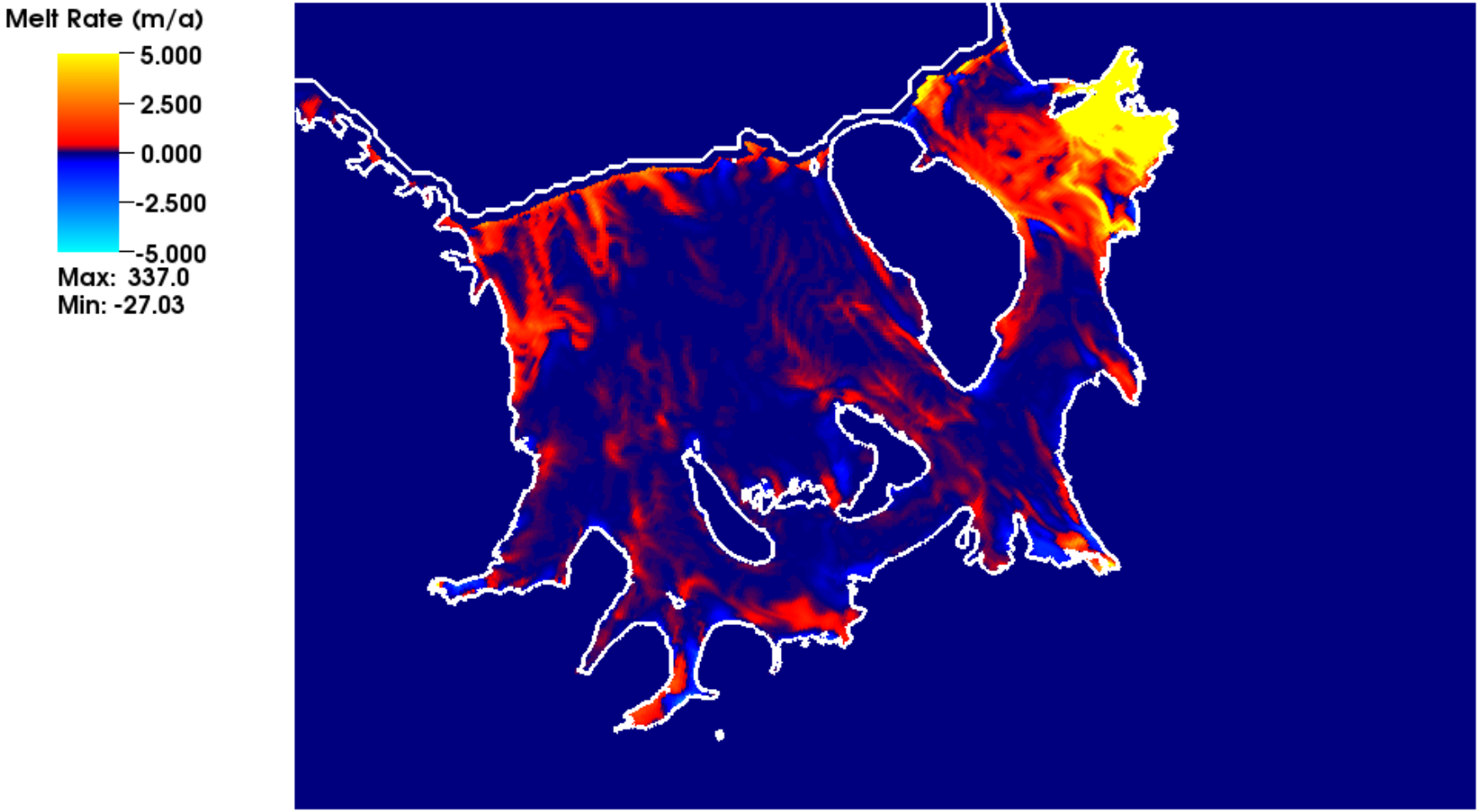


Time= 0.00 years

Ronne-Filchner Ice Shelf

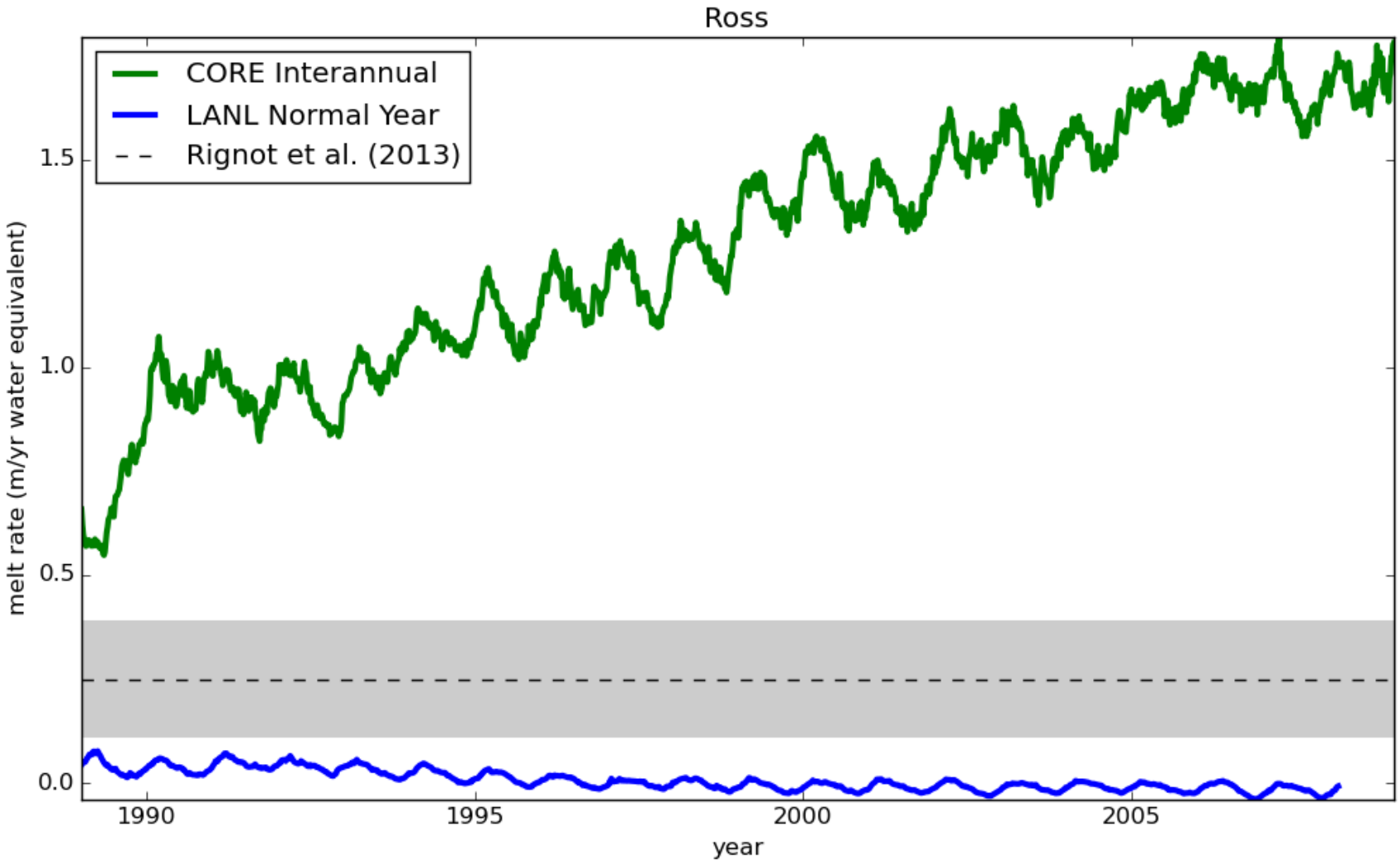


Ronne-Filchner Ice Shelf

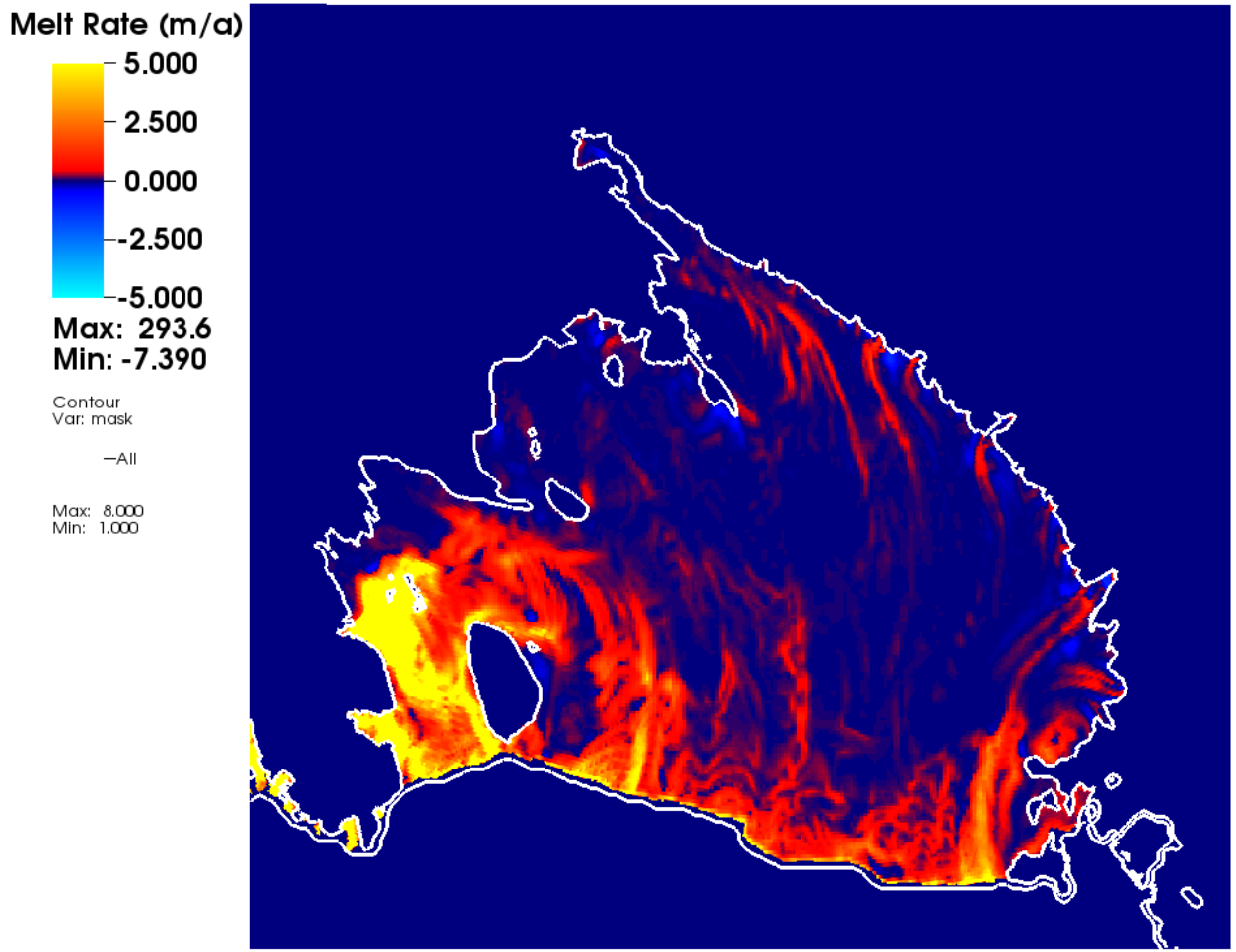


Time= 21.00 years

Ross Ice Shelf

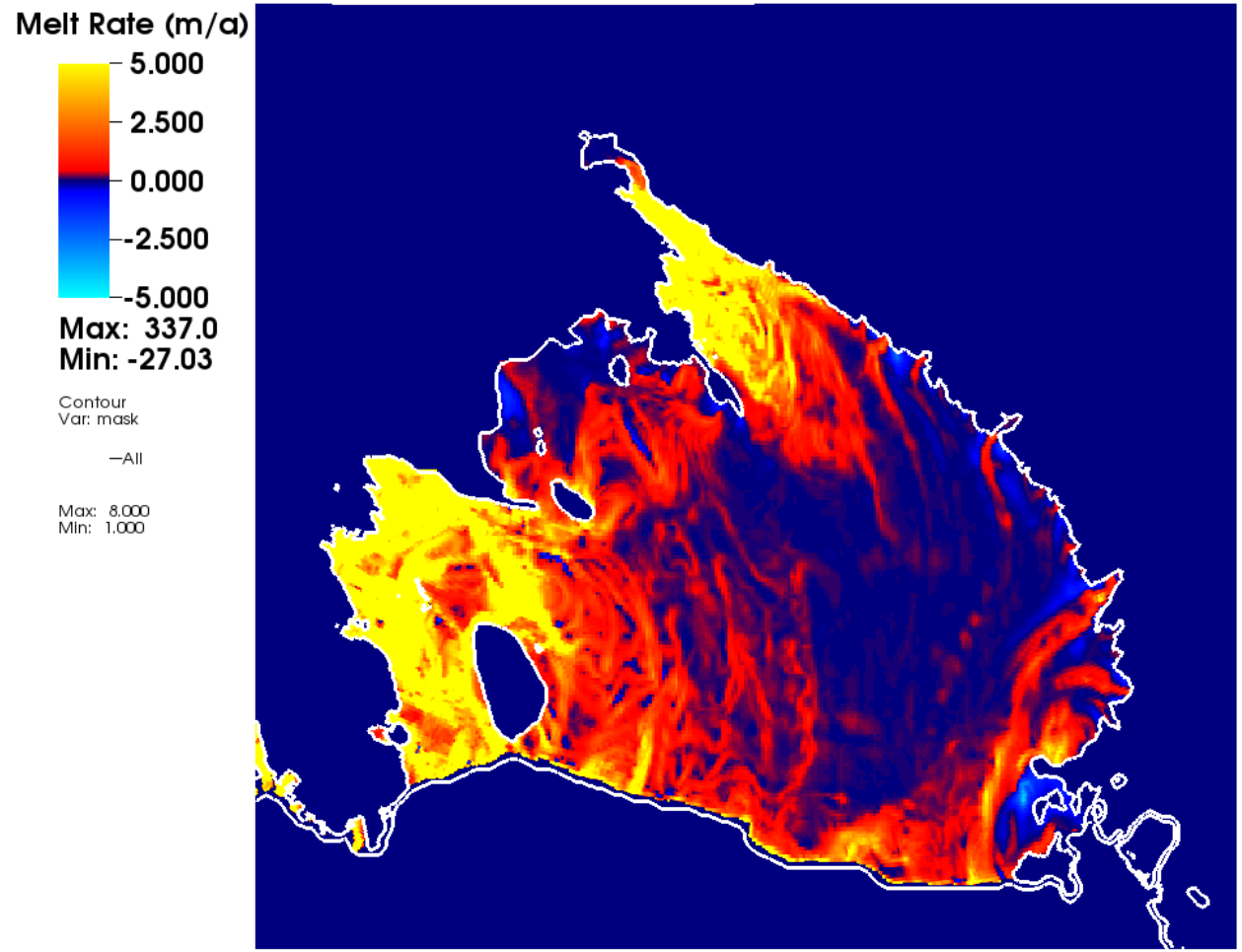


Ross Ice Shelf



Time= 0.00 years

Ross Ice Shelf



Time= 21.00 years

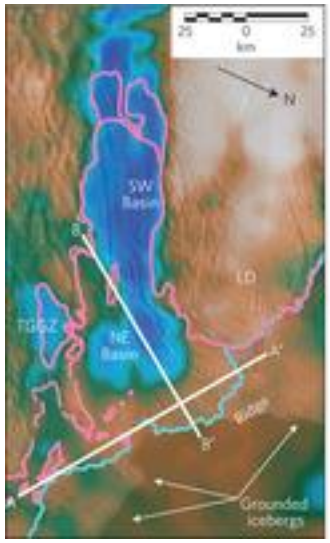
Next steps

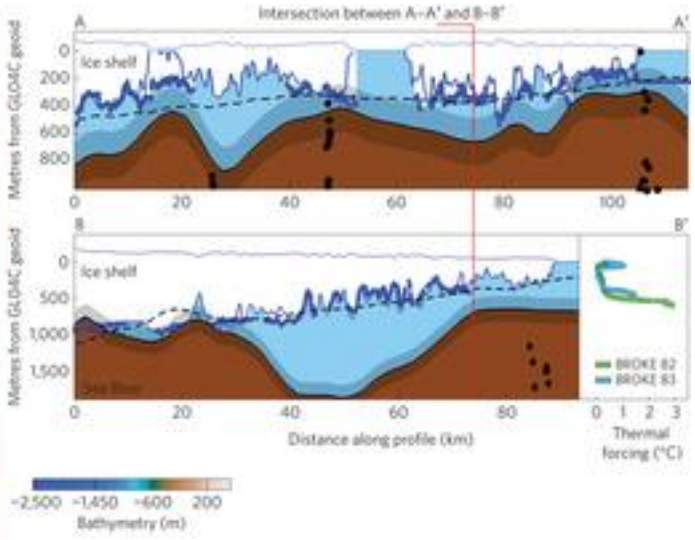
- Fix issues exposed during coupled run and try again.
  - Deepen bathymetry in problem regions (RTOPO1)
  - BISICLES initial condition -- realistic (Arthern?) SMB instead of steady-state

- More realistic climatology/forcing leading to “real” projections

- Hopefully by AGU…

Deepening bathymetry -- Totten

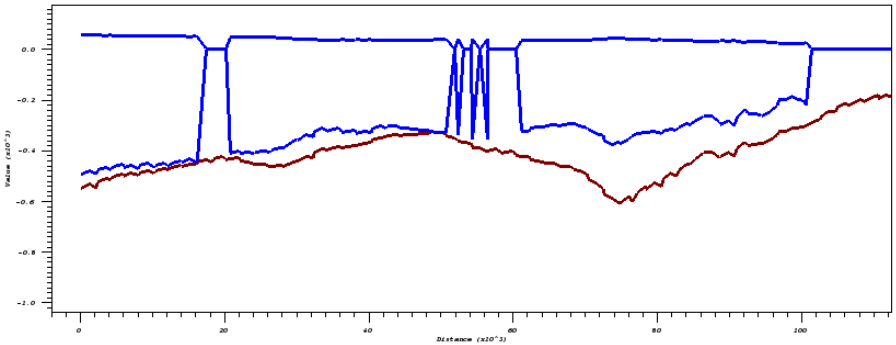


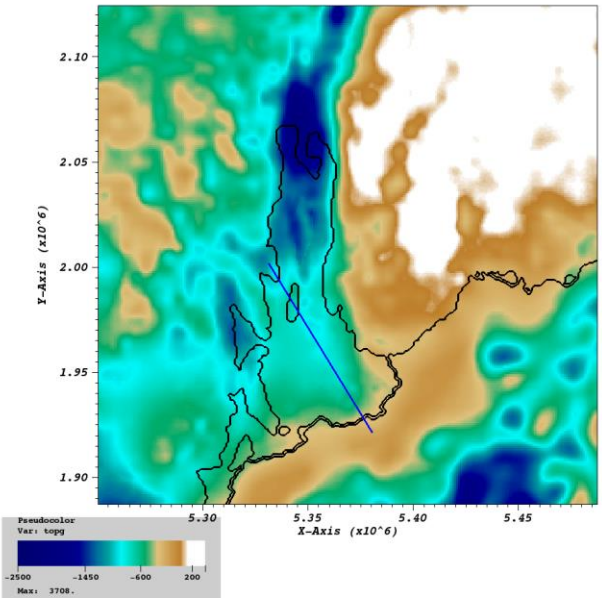


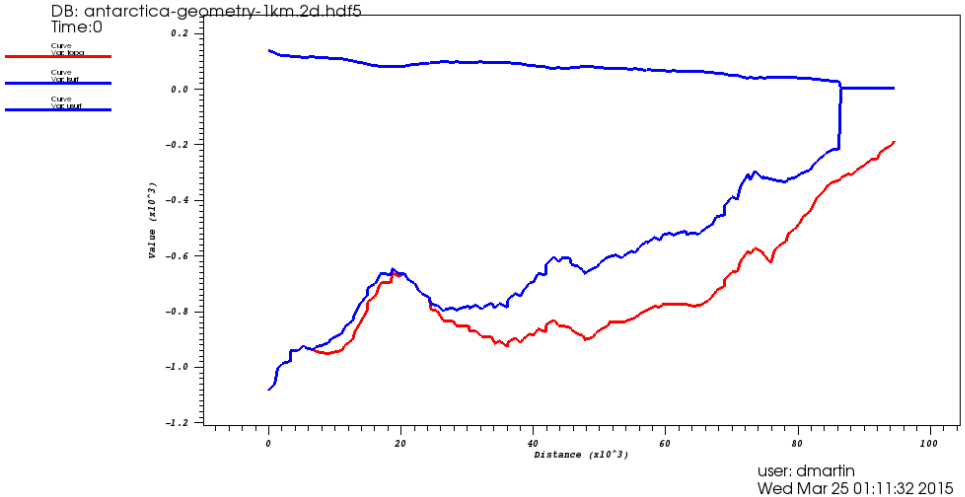
LETTERS
PUBLISHED ONLINE: 16 MARCH 2015 | DOI: 10.1038/NGEO2388
nature geoscience

Ocean access to a cavity beneath Totten Glacier in East Antarctica

J. S. Greenbaum[1]*, D. D. Blankenship[1], D. A. Young[1], T. G. Richter[1], J. L. Roberts[2,3], A. R. A. Aitken[4], B. Legresy[2,5,6], D. M. Schroeder[7], R. C. Warner[2,3], T. D. van Ommen[2,3] and M. J. Siegert[8]







user: dmartin
Wed Mar 25 01:11:32 2015

U.S. DEPARTMENT OF ENERGY | Office of Science | BISICLES | BERKELEY LAB | PIK | Los Alamos NATIONAL LABORATORY EST. 1943 | University of BRISTOL

Conclusions

- POP2x+BISICLES=POPSICLES coupled model
- Performed "high-resolution" pan-Antarctic simulations
  - Full Southern Ocean (0.1 degree)
  - Full-continent Antarctica (500m)
- Issues arising from coupled runs:
  - Need better subshelf bathymetry/geometry ("Olga's wish list")
  - Ocean forcing problematic
- Can still see "realistic" ice-ocean interactions

Thank you!